



Institute for Scientific Computing Research

ITS Lecture Series and Lecturer Biosketches



July 11, 2001

Computer Simulation of the Heart

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Abstract:

The study of blood flow in the cardiac chambers is complicated by the interaction of the blood with the flexible heart valve leaflets and with the muscular heart walls. These elastic and contractile tissues have certain properties in common with blood: they are incompressible and neutrally buoyant. These considerations suggest a unified treatment of cardiac mechanics in which the valves and heart walls appear as specialized regions of the fluid in which additional stresses appear. The additional stresses have a particular form, since they are fiber generated, the fibers in question are muscle fibers in the heart walls and collagen fibers in the heart valve leaflets.

We shall describe a computer model of the heart based on these principles and constructed, therefore, as a system of elastic and contractile fibers immersed in viscous incompressible fluid. This virtual heart includes representations of left and right atria; left and right ventricles; mitral, aortic, tricuspid, and pulmonic valves; pulmonary veins and ascending aorta; superior and inferior vena cavae and main pulmonary artery. Sources and sinks in the model veins and arteries connect the heart to pressure reservoirs representing the rest of the circulation. The equations of motion of the virtual heart are solved by the immersed boundary method, and the results are shown as a video animation of the beating heart.

Speaker's web page: <http://www.math.nyu.edu/faculty/peskin/>

Institution web page: <http://www.cims.nyu.edu/>

Biographical Sketch:

Charles S. Peskin

Charles S. Peskin's undergraduate studies were in Engineering and Applied Physics (A.B., Harvard, 1968) and his graduate studies were in Physiology (Ph.D., Albert Einstein College of Medicine, 1972). He now combines those interests as a Professor of Mathematics, Courant Institute of Mathematical Sciences, and Member of the Center for Neural Science, at New York University. His teaching at NYU ranges from graduate courses like "Mathematical Aspects of Heart Physiology" to a freshman seminar on "Computer Simulation."

Peskin has worked on several problems in which mathematics and computing are applied to biology and medicine. Some examples are blood flow in the heart, computer-assisted design of prosthetic cardiac valves, fiber architecture of the heart and its valves, fluid dynamics of the inner ear, photon noise in vision and nuclear medicine, and Brownian ratchet dynamics of biomolecular motors. He is the inventor of the immersed boundary method, which is broadly useful for problems of biological fluid dynamics. Peskin is a former MacArthur Fellow. He is a Member of the National Academy of Sciences and also of the Institute of Medicine.

May 9, 2001

Information Security: The Road Ahead

Eugene H. Spafford

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Abstract:

Melissa. ILOVEYOU. Web page defacement. Denial-of-service against e-commerce sites. Theft of laptops from the State Department. Information Warfare. Y2K. Napster. Hacking into Microsoft's network. Theft of information at the World Economic Forum. Fraudulent certificates from Verisign.

It is no longer possible to avoid stories of information loss, fraud, and compromise. Open any paper or magazine, or listen to the news (on-line, as well as in the standard media) and stories relating to information security are sure to be present.

So, what is the current state of information security? Are things getting better, or are they getting worse? And what are the challenges that we are likely to see in the near future?

This talk presents some highlights of what is happening in information security, and what is yet to happen. We also include some discussion of the nature of infosec-related challenges that we are likely to face—and few of them are based solely in technology.

Biographical Sketch:

Eugene H. Spafford

Eugene H. Spafford is a professor of Computer Sciences at Purdue University, a professor of Philosophy, and is Director of the Center for Education Research Information Assurance and Security. CERIAS is a campus-wide multi-disciplinary Center, with a broadly focused mission to explore issues related to protecting information and information resources. He has written extensively about information security, software engineering, and professional ethics. He has published over 100 articles and reports, has written or contributed to over a dozen books, and he serves on the editorial boards of most major infosec-related journals.

Dr. Spafford is a Fellow of the ACM, a Fellow of the AAAS, a Fellow of the IEEE, and a charter recipient of the Computer Society's Golden Core award. In 2000, he was named as a CISSP, honoris causa. Among his many activities, he is chair of the ACM's U.S. Public Policy Committee, a member of the Board of Directors of the Computing Research Association, and a member of the U.S. Air Force Scientific Advisory Board. He was the year 2000 recipient of the NIST/NCSC National Computer Systems Security Award, generally regarded as the field's most significant honor in information security research, and was named as one of the "Five Most Influential Leaders in Information Security" by the readers and editors of Information Security in 1999. In 2001, he was named as one of the recipients of the Charles B. Murphy award, Purdue University's highest award for outstanding undergraduate teaching. In his spare time, Spaf wonders why he has no spare time.

*More information may be found at
<http://www.cerias.purdue.edu/homes/spaf/>*

March 28, 2001

Computing the Cosmic Web and the Evolution of the Universe

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Abstract:

Our physical universe is an initial value problem amenable to direct numerical simulation. With known laws of physics and initial conditions, multiresolution numerical algorithms, and sufficient computing power, we are able to simulate the formation and evolution of cosmic structures (galaxies, superclusters, etc.) from shortly after the Big Bang to the present day. In this talk, I will describe how this is done and what we have learned.

Recent astronomical observations have strongly constrained the numerical values of the cosmological parameters governing the global geometry and expansion of the universe, the mean density of its matter constituents, and have strongly constrained the power spectrum of primordial matter fluctuations that seeded the formation of galaxies and clusters. We thus have arrived at a standard cosmological model whose consequences for structure formation are being explored using multiphysics, multiscale numerical simulations on terascale platforms.

A generic feature of these models is that gravity organizes matter into a filamentary network termed the cosmic web. The cosmic web evolves with time nearly self-similarly, with small length and mass scales going nonlinear at early times, followed by larger scales at later times. Structures in the universe thus are predicted to be built up hierarchically “bottom-up,” in agreement with observations. In this talk, I will explore the implications of the standard model to the first generation of cosmic structures and their influence on subsequent generations.

The principal computational challenges are twofold: the vast range of length scales that must be resolved simultaneously in a single simulation (multiscale challenge), and the large number of physical processes that must be included for accurate predictions (multiphysics challenge). I describe a decade-long code development quest that has resulted in the world's first adaptive mesh refinement (AMR) application for cosmological structure formation. Optimizing this code for current terascale systems has proved to be an interesting challenge, as I will relate. Visualizing the results of multiscale AMR simulations has required the development of new tools, which we have made publicly available.

Speaker's web page: <http://www.ucsd.edu/>

Web links:

Laboratory for Computational Astrophysics (<http://lca.ncsa.uiuc.edu/lca.html>)

LCA Vision (<http://zeus.ncsa.uiuc.edu/~miksa/LCAVision.html>)

Grand Challenge Cosmology Consortium
(<http://lca.ncsa.uiuc.edu/GC3Home.html>)

Biographical Sketch:

Michael L. Norman

Michael Norman earned a B.S. in astronomy at the California Institute of Technology in 1975, and M.S. and Ph.D. degrees in engineering and applied science from UC Davis in 1976 and 1980, respectively, while a student employee in B Division at LLNL. Working under the supervision of James R. Wilson, he did a thesis in computational astrophysics, a field he has worked in ever since. Norman has worked on a variety of problems in astrophysics and cosmology, including star formation, supernova remnants, astrophysical jets, and most recently, the formation of cosmic structure.

He is currently a professor of physics at the University of California, San Diego, where he directs the Laboratory for Computational Astrophysics. He has previously held positions at the Max Planck Institute for Astrophysics, Los Alamos National Lab, and for 14 years he was a senior research scientist and team leader at the National Center for Supercomputing Applications (NCSA) at the University of Illinois, Urbana-Champaign.

In 1992, Norman founded the Laboratory for Computational Astrophysics (LCA), which develops and disseminates application software for astrophysical fluid dynamical simulations. The ZEUS family of radiation magnetohydrodynamic codes is in worldwide use. He is currently working on numerical algorithms for 3D radiative transfer and radiation hydrodynamics for astrophysical and cosmological applications. While at Illinois, he was also a scientific team leader of the ASCI ASAP Center for the Simulation of Advanced Rockets.

He has received Germany's Alexander von Humboldt Research Prize, the IEEE Sidney Fernbach Award, as well as several Supercomputing'XY HPCC Challenge Awards.

January 24, 2001

Abstract:

Wavelets: An Overview, with Recent Applications

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Wavelets have emerged in the last decade as a synthesis from many disciplines, ranging from pure mathematics (where forerunners were used to study singular integral operators) to electrical engineering (quadrature mirror filters), borrowing in passing from quantum physics, from geophysics, and from computer-aided design. The first part of the talk will present an overview of the ideas in wavelet theory, in particular wavelet bases. The second part of the talk will discuss some recent applications.

Speaker's web page: <http://www.princeton.edu/~icd/>

Institution web page: <http://www.princeton.edu/>

Biographical Sketch:

Ingrid Daubechies

Ingrid Daubechies received her Bachelor's and Ph.D. degrees from the Free University in Brussels, Belgium, in physics, in 1975 and 1980, respectively. She held a research position at the Free University until 1987. From 1987 to 1994 she was a member of the technical staff at AT&T Bell Laboratories, during which time she took leaves to spend six months (in 1990) at the University of Michigan, and two years (1991-93) at Rutgers University. She is now a Professor of Mathematics at Princeton University and is affiliated with Princeton's program in Applied and Computational Mathematics. Her research interests focus on the mathematical aspects of time-frequency analysis, in particular wavelets, as well as applications.

In 1998 she was elected to the National Academy of Sciences and became a Fellow of the Institute of Electrical and Electronics Engineers. The American Mathematical Society awarded her a Leroy P. Steele prize for exposition in 1994 for her book "Ten Lectures on Wavelets," as well as the 1997 Ruth Lyttle Satter prize. Dr. Daubechies was awarded the National Academy of Science Medal in Mathematics in 2000, and the Eduard Rhein Foundation 2000 Basic Research Award for the invention, the mathematical advancement, and the application of wavelets. From 1992 to 1997 she was a fellow of the John D. and Catherine T. MacArthur Foundation. She is a member of the American Academy of Arts and Sciences, the American Mathematical Society, the Mathematical Association of America, the Society for Industrial and Applied Mathematics, and the Institute of Electrical and Electronics Engineers.

November 15, 2000

The Analysis of Algorithms: Experiments versus Theory

David S. Johnson

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Abstract:

A common response to a new theoretical result about an algorithm's performance is "Yes, very interesting, but how does it work in practice?" A common response to a paper presenting new experimental results about an algorithmic performance is "Interesting, but do these specific data points tell us anything of more general significance?" Thus, theory and experiment are often placed in opposition. In this talk I will show how they in fact can work together, with illustrations from the study of the "bin packing" problem.

In the simplest version of bin packing, one is given a sequence of items with sizes between 0 and 1, and desires to pack them into a minimum number of unit-capacity bins. This problem has many applications, from optimizing file storage on floppy disks to packing the data for Internet phone calls into ATM packets. The bin packing problem has for three decades served as one of the main test beds for new algorithmic ideas and modes of analysis. From the very beginning, experimental analysis has proceeded in parallel with theoretical work, but in recent years feedback between the two has led to surprising insights and new algorithms of unexpected power.

Speaker's web page: <http://www.research.att.com/~dsj/>

Institution Web page: <http://www.research.att.com/info/Projects/>

Biographical Sketch:

David S. Johnson

David S. Johnson was born in Washington, DC, in 1945 and grew up in Milwaukee, Wisconsin. He received a BA summa cum laude in Mathematics from Amherst College in 1967, and a Ph.D. from MIT in Mathematics in 1973, with a thesis entitled “Near-Optimal Bin Packing Algorithms.” In 1973 he joined AT&T where he has worked to the present day (although his immediate employer has changed from Bell Labs to AT&T Bell Laboratories to AT&T Labs during the course of AT&T’s many divestitures). He currently heads the Algorithms and Optimization Department at AT&T Labs - Research in Florham Park, NJ.

Dr. Johnson is perhaps most widely known for the book *Computers and Intractability: A Guide to the Theory of NP-Completeness*, which he co-authored with Michael Garey and for which they won the 1979 Lanchester Prize of the Operations Research Society of America. NP-complete problems are conjectured to be impossible to solve exactly with provably efficient algorithms, and throughout his research career Dr. Johnson has been interested in how one copes with such theoretical intractability. He was one of the pioneers in the field of performance guarantees for “approximation algorithms,” fast algorithms for optimization problems that are not guaranteed to find optimal solutions, but hope to find near-optimal ones. An example of such an algorithm is the “First Fit Decreasing” algorithm for bin packing, which he proved in his Ph.D. thesis never uses more than $11/9$ times the optimal number of bins (at least in an asymptotic sense).

In recent years, he has become interested in the average-case analysis of heuristics, and his research has emphasized the interplay between theoretical and experimental analysis in this domain. His experimental work has concentrated on fundamental problem domains such as graph coloring, graph partitioning, bin packing, and the traveling salesman problem, and in the comparison between classical approaches to these problems and new “metaheuristic” approaches such as simulated annealing and genetic algorithms. He has written and talked extensively on methodological issues related to the experimental analysis of algorithms and has overseen the ongoing series of DIMACS Implementation Challenges, which he initiated in 1990.

He has over 100 scientific publications, including 23 editions of a column on the theory of NP-completeness that he writes for the Journal of Algorithms. He is a Fellow of the Association for Computing Machinery (ACM) and is currently a member of the ACM Council and the DIMACS Executive Committee, having served previously as Chair of the ACM Special Interest Group on Algorithms and Computation Theory (SIGACT) and on the Board of the Computing Research Association (CRA).